A new method of measurement of the velocities of solar neutrinos

Elmir Dermendjiev

"Mladost-2", block 224, entr.1, apt.13, 1799-Sofia, Bulgaria

February 9, 2008

Abstract

A new method of measurement of the velocities of solar electron antineutrinos is proposed. The method is based on the assumption, that if the neutrino detector having a shape of a pipe and providing a proper angular resolution, is directed onto the optical "image" of the sun, then it would detect solar neutrinos with velocities $V_{\tilde{\nu}_e} = c$. Here c is the velocity of light. It is expected that the less is the value of $V_{\tilde{\nu}_e}$, the larger would be the angular lagging of the "image" of these neutrinos relative to the position of the optical "image" of the sun. Therefore, one can detect solar neutrinos with different energies by changing the angle between the axis of a detector pipe and the direction to the "image" of the sun. Also, the method gives unique possibility to check hypotheses predicting an existence of solar neutrinos with $V_{\tilde{\nu}_e} > c$. In this case the "image" of such solar neutrinos on the sky should pass the "image" of the sun.

PACS number: 03.30;
Solar electron antineutrino; Velocities of solar
electron antineutrinos; method of measurement of velocities of solar
electron antineutrinos.

1   Introduction

The problem of a generation of the solar energy and its nature is probably the most important astrophysical one. At present the most spread notion on the origin of the solar energy is based on the assumption that it appears as a result of thermonuclear reactions inside the sun. Briefly, the process of transformation of hydrogen to helium is accompanied by emission of electron antineutrinos $\tilde{\nu}_e$ [1]. Some astrophysical solar models predict different yields of groups of antineutrinos with different energies E_ν. In regard with the "Standard Solar Model" (SSM) most of antineutrinos (~99.75%) should have an energy in the range of $0 < E_\nu < 420 keV$ (so - called "PP1" - group of neutrinos). The group of "PeP" - antineutrinos has a fixed energy $E_\nu = 1.44 MeV$, but much lower intensity than the first group. A group "HeP" has an energy spectrum up to

$18.6 MeV$ and the yield of ˜$10^{-5}\%$, etc. In addition, the theory predicts the existence of two other groups of antineutrinos:"PP2" and "PP3". They have mono-energetic and continuous energy spectra respectively and are important for the theory. Other source of antineutrinos is so-called "carbon-nitrogen" (CN) cycle, that generates two more groups of antineutrinos with $E_\nu = 1.2 MeV$ and $1.7 MeV$. Thus, to check the SSM one needs to perform very complicated experiment that includes a spectrometry of the energies of solar antineutrinos and a measurement of the intensities of these groups of $\widetilde{\nu}_e$. Unfortunately, at present such experiment is out of our technical possibilities due to many reasons. The most serious experimental difficulty in performing astrophysical experiments with solar $\widetilde{\nu}_e$ is an extremely low absorption cross section $\sigma_a(\widetilde{\nu}_e)$ of electron antineutrinos by nuclei, which is estimated to be of ˜$10^{-43} cm^2$[2].

At present solar $\widetilde{\nu}_e$ are studied in a few laboratories [1,3] by using giant neutrino detectors, which are briefly discussed below. Unfortunately, these facilities are not intended for detection of the relatively low energy solar antineutrinos or their values of $V_{\widetilde{\nu}_e}$.

Below, a method that might be suitable for measurements of the velocities $V_{\widetilde{\nu}_e} < c$ of solar electron antineutrinos is proposed. One can hope that the experimental information obtained by proposed method might be useful for further development of the SSM.

At present, the proposed method of measurement of the velocities of solar antineutrinos is the only method, that allows to search whether some of them have values of $V_{\widetilde{\nu}_e} > c$. Possible existence of such hypothetical solar antineutrinos is discussed in [4]. This hypothesis is inconsistent with the theory of relativity. However, by using the method proposed below, one has the unique possibility to find such super-fast particles with $V_{\widetilde{\nu}_e} > c$, if they exist, or to refute the hypothesis [4].

2 A method of measurement of the velocities of solar antineutrinos

The proposed method of measurement of the velocities $V_{\widetilde{\nu}_e}$ of solar electron antineutrinos is based on the simple and clear idea that the position of their "images" on the sky relative to the optical "image" of the sun should depend on the value of $V_{\widetilde{\nu}_e}$. Assume, that the observer has a "*pipe*"-type neutrino detector that follows the movement of the optical "image" of the sun on its sky trajectory. Also, assume that this detector has an angular resolution $\Delta\alpha$ comparable with the angular size of the sun, i.e. $\Delta\alpha \leq 0,5^o$. Then, if $V_{\widetilde{\nu}_e} = c$, both the neutrino and the sun "images" should coincide. In the case when $V_{\widetilde{\nu}_e} < c$, the "image" of given group of neutrinos with certain value of $V_{\widetilde{\nu}_e}$ is expected to have an angular lagging relative to the optical "image" of the sun. It is clear that the less is the value of $V_{\widetilde{\nu}_e}$, the larger would be the angular lagging of $\widetilde{\nu}_e$ having that value of $V_{\widetilde{\nu}_e}$. In the case when $V_{\widetilde{\nu}_e} > c$, one should expect that the "image" of such neutrinos should pass the "image" of the sun. Thus, if the neutrino detector

follows the "image" of the sun with a constant angle β of lagging or passing, then one can determine the value of $V_{\widetilde{\nu}_e}$.

How large are the expected values of β? The angular velocity ω of the optical "image" of the sun relative to the Earth is of $\omega = 0.00417 deg.s^{-1}$. Two cases are discussed below:

a) $V_{\widetilde{\nu}_e} < c$. If β does not exceed a few degrees, then the value of $V_{\widetilde{\nu}_e}$ can be estimated by using the following approximate relationship:

$$V_{\widetilde{\nu}_e} \approx \frac{L}{480 + \beta/\omega} \tag{1}$$

Here $L = 1.45.10^{11}m$. If, for instance, $V_{\widetilde{\nu}_e} = 10^8 m.s^{-1}$ or $3.10^7 m.s^{-1}$, then the value of β is approximately 4° or 18°.

b) $V_{\widetilde{\nu}_e} > c$. In this case the "image" of such super-fast hypothetical neutrinos should

pass the optical "image" of the sun with an angle $\beta\prime$. Then a similar relationship can be used:

$$V_{\widetilde{\nu}_e} \approx \frac{L}{480 - \beta\prime/\omega} \tag{2}$$

It is interesting to note that if $V_{\widetilde{\nu}_e} \to \infty$, then the maximum value of β' is close to 2°, i.e. of ˜ 4 angular sizes of the diameter of the sun. This means, that if such super-fast solar neutrinos would exist, than they could be found experimentally.

3 Discussion

The study of the properties of solar neutrinos in modern laboratories [1,3] is an extremely difficult task. As it was briefly mentioned above, there are some experimental difficulties originated by very low value of the absorption cross section $\sigma_a(\widetilde{\nu}_e)$ of solar antineutrinos by nuclei [2]. This leads to a lack in detection rate even in the case of using huge solar neutrino detectors. Another difficult problem is the necessity the detector background to be minimized. It requires neutrino detectors to be situated underground.

To conclude whether the proposed method could be applied in solar neutrino experiments, brief comparison between some of the existing methods of detection of solar neutrinos and the proposed method is presented below.

Up to now, there are only a few experimental studies of solar neutrinos, which are not considered in this paper. However, all of them were performed with giant neutrino detectors, like the solar neutrino detector designed by Davis [1]. This large facility has 615 tons of C_2Cl_4, used as a detector substance. The detection of solar antineutrino is based on the reaction of absorption of $\widetilde{\nu}_e$ by a nucleus of ^{37}Cl [5]:

$$^{37}Cl + \widetilde{\nu}_e \to^{37} Ar + e^- \tag{3}$$

This reaction has a threshold of $0.816 MeV$. The detection of solar antineutrinos is based on the radiochemical reaction (3) and the detector cannot be used for energy measurements. The SNO [4] is another large facility that contains 1000 tons of D_2O for study of the properties of solar neutrinos. The detection of $\widetilde{\nu}_e$ is released when $\widetilde{\nu}_e$ interacts with deuterium nuclei:

$$d + \widetilde{\nu}_e \rightarrow p + p + e^- \tag{4}$$

The SNO facility is intended to be used manly for detection of high energy neutrinos. Therefore, it is not suitable for spectrometry of energies or velocities of solar antineutrinos. On the other hand, further development of the SSM needs the intensities of different groups of antineutrinos with fixed energies $E_{\widetilde{\nu}_e}$ to be known with permanently arising accuracy. Since there are no neutrino detectors capable to measure the energies of solar neutrinos, one can hope that the proposed method of measurement of the velocities of neutrinos could, to some extend, contribute the solution of this very important problem of generation of the solar energy. The counting rate $N_{\widetilde{\nu}_e}$ of a "pipe"-type neutrino detector is estimated below. It is desirable the value of $\Delta\alpha$ ~(Φ/L) of this detector to be comparable with the angular size of the optical "image" of the sun, which is of ~0.5^o. Also, it is necessary the value of $\Delta\alpha$~0.5^o to be kept, if one would search for hypothetical "super-fast" neutrinos [4]. Suppose that the length L and the diameter Φ of the pipe are of $11.5m$ and $0.1m$ respectively. It seems to be reasonable, a detection technique, similar to that described by Reines at al. [2], to be chosen. The pipe contains liquid scintillator with small amount of Cd (or Gd). This pipe is inserted into the outer pipe with larger diameter and six radial sections along the pipe. All radial sections are filled with liquid scintillator. Photomultiplier tubes are mounted along the section sides of outer pipe. The detection of solar electron antineutrino is based on the following nuclear reaction:

$$\widetilde{\nu}_e + p \rightarrow n + e^+ \tag{5}$$

Two annihilation gamma-quanta mark the reaction (5) and ~ six slow neutron capture gamma-quanta are emitted due to the $Cd(n, \gamma)$ reaction [2]. A delayed coincidence technique used in [2] provides quite low detection background. Similar technique was successfully used in fission [6] and sub-threshold fission experiments [7] with U, Pu and Np isotope targets having very high specific α - and γ - activity. The counting rate $N_{\widetilde{\nu}_e}$ can be estimated by using the approximate relationship:

$$N_{\widetilde{\nu}_e} \approx n\sigma_a(\widetilde{\nu}_e, p)\phi\epsilon_{\widetilde{\nu}_e}SLt \tag{6}$$

Here, n is the number of hydrogen atoms in$1 cm^3$ of liquid scintillator, $\sigma_a(\widetilde{\nu}_e, p) = 1.2.10^{-43}cm^2$[2]. The approximate value of the flux of solar electron antineutrinos at the surface of the Earth is accepted to be of $\phi \approx 5.10^{10}cm^{-2}s^{-1}$. The detection efficiency $\epsilon_{\widetilde{\nu}_e}$ is estimated to be of ~0.3 if a delayed coincidences between two annihilation gamma-quanta and more than three captured gamma-quanta are realized. In Eq.(6) $S = (\pi/4)\Phi^2$, were $\Phi = 0.1m$, $L = 11.5m$ and $t = 1s$.

Using these numbers one gets an estimated value of $N_{\widetilde{\nu}_e} \sim 10^{-4} s^{-1}$, which means that one could collect ~3.10^3 events per year. Further optimization of the "pipe"-type neutrino detector might strongly reduce the measurement time compare to the estimated value. Brief consideration of different methods of detection of electron antineutrinos, allows to be concluded, that the proposed method could be used for measurements of velocities of solar antineutrinos and, thus, provide a new experimental data for further development of the SSM. Also, having a moderate size, the proposed "*pipe*"-type neutrino detector can ensure a reasonable time of measurements. However, the most important preference of proposed method is the opportunity to search for existence of neutrinos with $V_{\widetilde{\nu}_e} > c$. Based on the theory of relativity, one should not expect an existence of such neutrinos in Nature. Then, the experiment based on the proposed method of measurement the velocities of neutrinos would be a strong confirmation of the theory of relativity. But, if neutrinos with $V_{\widetilde{\nu}_e} > c$ exist, one should expect deep change of our understanding of Nature.

References

[1] Davis R. Bull. Amer. Phys. Soc. 1959, v.4, p.217 Davis R. Phys. Rev. Lett., 1964, v.12, p.303

[2] Reines F., C.L. Cowan Jr., F.B. Harrison, A.D. McGuire, H.W. Kruse Phys. Rev., 1960, v.117, p.159

[3] SNO - collaboration, nucl - ex/0309004

[4] Dermendjiev Elmir,nucl - th/0505040

[5] Pontecorvo Bruno, Chalck River Report, PD-205,1946

[6] Wang Shi-di, Wang Yun-chang, E. Dermendjiev, Yu.V. Ryabov "Physics and Chemistry of Fission", 1965, Vienna, v.1, p.287 Yu.V. Ryabov, WangYun-chang, E. Dermendjiev, Chjang Pey-shu Yadernaya Fizika, 1967, v.5, p.925

[7] Borzakov S.B., E.Dermendjiev, A.A. Goverdovsky, A.Kalinin, V.Konovalov, I. Ruskov, S.M.Soloviov, Yu.S.Zamiatnin Yadernaya Fizika, 1996, v.59, p.1175